Photoelectrochemical Properties of Fe$_2$O$_3$/CuFe$_2$O$_4$

Composite Nanorod Arrays as Photoanodes

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Solar water splitting is arguably one of the most important chemical reactions because its oxidation process produces oxygen for the world and the sun illuminates the earth with an enormous amount of energy daily. Hematite ($\alpha$-Fe$_2$O$_3$) is one promising candidate for the water splitting due to its adequate absorption of visible light and stability under water oxidation conditions$^{1,2}$. Also, hematite is nontoxic and abundant which make it a potential material for large scale applications. $\alpha$-Fe$_2$O$_3$ is an n-type semiconductor that has many excellent properties for use as a photoanode in the photoelectrolyzation of water.$^3$ Compared to other abundant metal oxides, $\alpha$-Fe$_2$O$_3$ hematite has the advantage that its bandgap is about 2.1 eV allowing for the absorption of roughly 40% of the solar spectrum. Many of the desirable properties of Fe$_2$O$_3$ are shared with Fe-based ternary oxides classified as ferrites that have a chemical formula of MFe$_2$O$_4$ where M is divalent ion such as Cu$^{2+}$ and Co$^{2+}$. The bandgap of ferrites is comparable to that of $\alpha$-Fe$_2$O$_3$ and is also chemically and photochemically stable in basic media; consequently n-type MFe$_2$O$_4$ is promising as a photoanode for the photoelectrolysis of water. In this work, we synthesized Fe$_2$O$_3$/CuFe$_2$O$_4$ composite electrodes and investigated their photoelectrochemical properties as the photoanodes.

Hematite array nanorods were fabricated on FTO coated glass substrates by hydrothermal treatment of a mixture of FeCl$_3$ and NaNO$_3$/CuNO$_3$ ethanol solutions with hydrochloric acid. The Fe$_2$O$_3$/CuFe$_2$O$_4$ composite electrodes were prepared by submerging the hematite nanorods in the solution of Cu(NO$_3$)$_2$ for 3 h at room temperature and then annealed in the air at 520°C for 12 h with a ramping rate of 2 °C/min. The morphologies and nanoparticle sizes of the hematite nanorods were characterized with a field emission scanning electron microscope (SEM, JEOL JSM-6700F). The hematite nanostructured films on FTO substrates were characterized with a powder X-ray diffractometer (XRD, Rigaku D/max-RA) using a Cu Kα radiation source ($\lambda = 1.5406 $ Å). Diffraction patterns were recorded from 20 to 70° with a step size of 0.04° at 1°/min. Hematite nanorod arrays were characterized with a three-electrode configuration with a hematite film as the working photoelectrode, Ag/AgCl as the reference electrode, and platinum foil as the counter electrode in 1 M NaOH electrolyte. In the dark and under the illumination of AM 1.5G simulated solar light (100 mW/cm$^2$) in 1 M NaOH electrolyte (pH 13.4) with a scan rate of 10 mV/s.

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